The Large Underground Xenon (LUX) Dark Matter Experiment

www.luxdarkmatter.org

Carlos Hernandez Faham
Brown University

BNL Forum, May 27 2010

If you only have 30 seconds...

LUX

Large Underground Xenon

- Ultra-low background, **350 kg liquid xenon** time-projection chamber
- Aims to directly detect the (potentially) rare interactions between **WIMPs** and us
- To be deployed underground at **SUSEL** (Homestake mine in SD) in 2011
- It's **big**: in less than 2 days, it will surpass all current limits set today

The LUX Collaboration

Formed in 2007, fully funded DOE/NSF in 2008

Brown
XENON10, CDMS

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Simon Fiorucci	Postdoc
Monica Pangilinan	Postdoc
Luiz de Viveiros	Graduate Student
Jeremy Chapman	Graduate Student
Carlos Hernandez Faham	Graduate Student
David Malling	Graduate Student
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SNO, Borexino, XENON10, CDMS

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Mike Dragowsky	Research Associate Professor
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Ken Clark	Postdoc
Karen Gibson	Postdoc
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Chang Lee	Graduate Student

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BABAR, ATLAS

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Lawrence Berkeley
SNO, KamLAND

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Kevin Lesko	Senior Physicist
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Brian Fujikawa	Scientist
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Lawrence Livermore
XENON10

Adam Bernstein	PI, Leader of Adv. Detectors Group
Dennis Carr	Senior Engineer
Kareem Kazkaz	Staff Physicist
Peter Sorensen	Postdoc

University of Maryland
EXO

Carter Hall	Professor
Douglas Leonard	Postdoc

SD School of Mines
IceCube

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ZEPLIN II

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Robert Webb	Professor
Rachel Mannino	Graduate Student
Tyana Stiegler	Graduate Student
Clement Sofka	Graduate Student

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Robert Svoboda	Professor
Richard Lander	Professor
Britt Hollbrook	Senior Engineer
John Thomson	Engineer
Matthew Szydagis	Postdoc
Jeremy Mock	Graduate Student
Melinda Sweany	Graduate Student
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ZEPLIN II

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Udo Shroeder	Professor
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Xiaoyi Yang	Graduate Student

Yale
XENON10, CLEAN-DEAP

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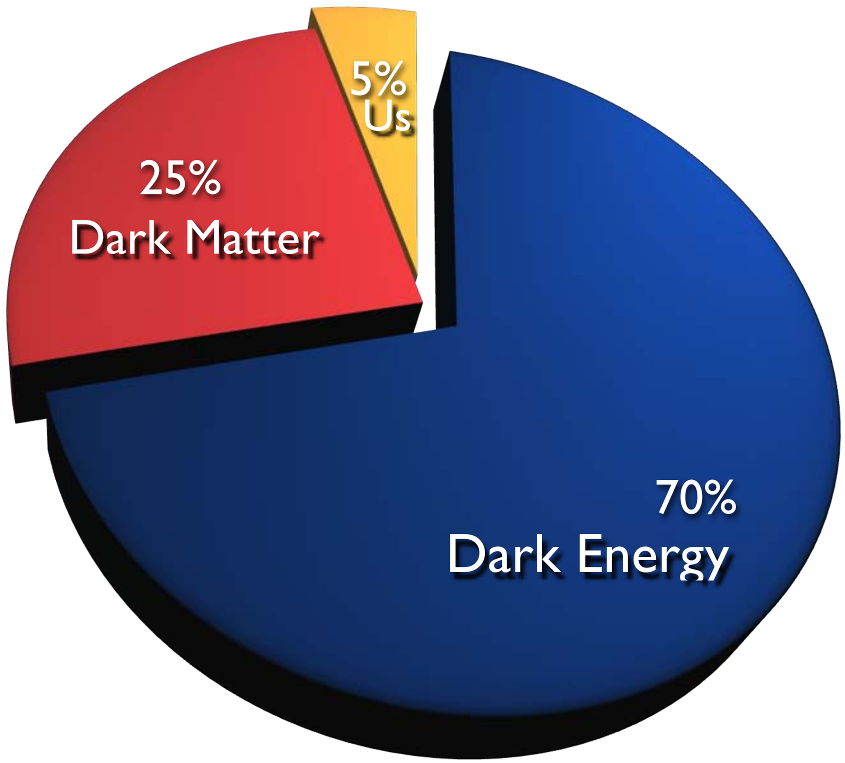
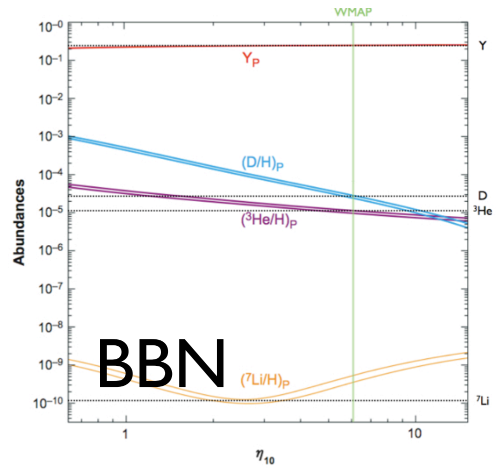
James Nikkel	Research Scientist
Sidney Cahn	Research Scientist
Alexey Lyashenko	Postdoc
Ethan Bernard	Postdoc
Louis Kastens	Graduate Student
Nicole Larsen	Graduate Student

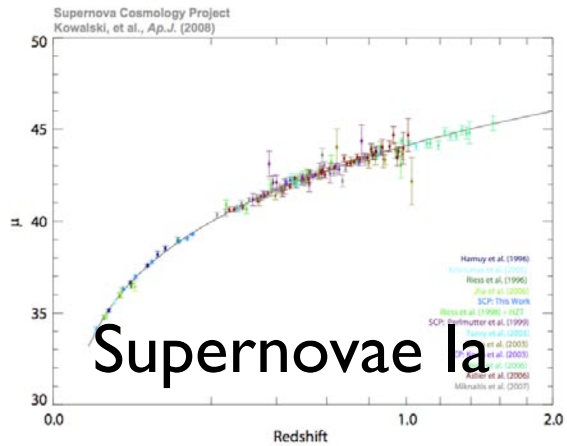
The Motivation

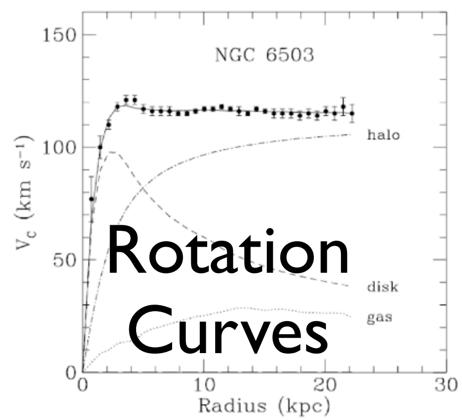
WIMPs?

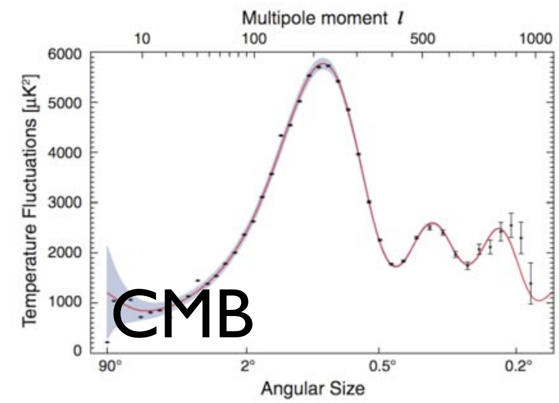
Dark Matter







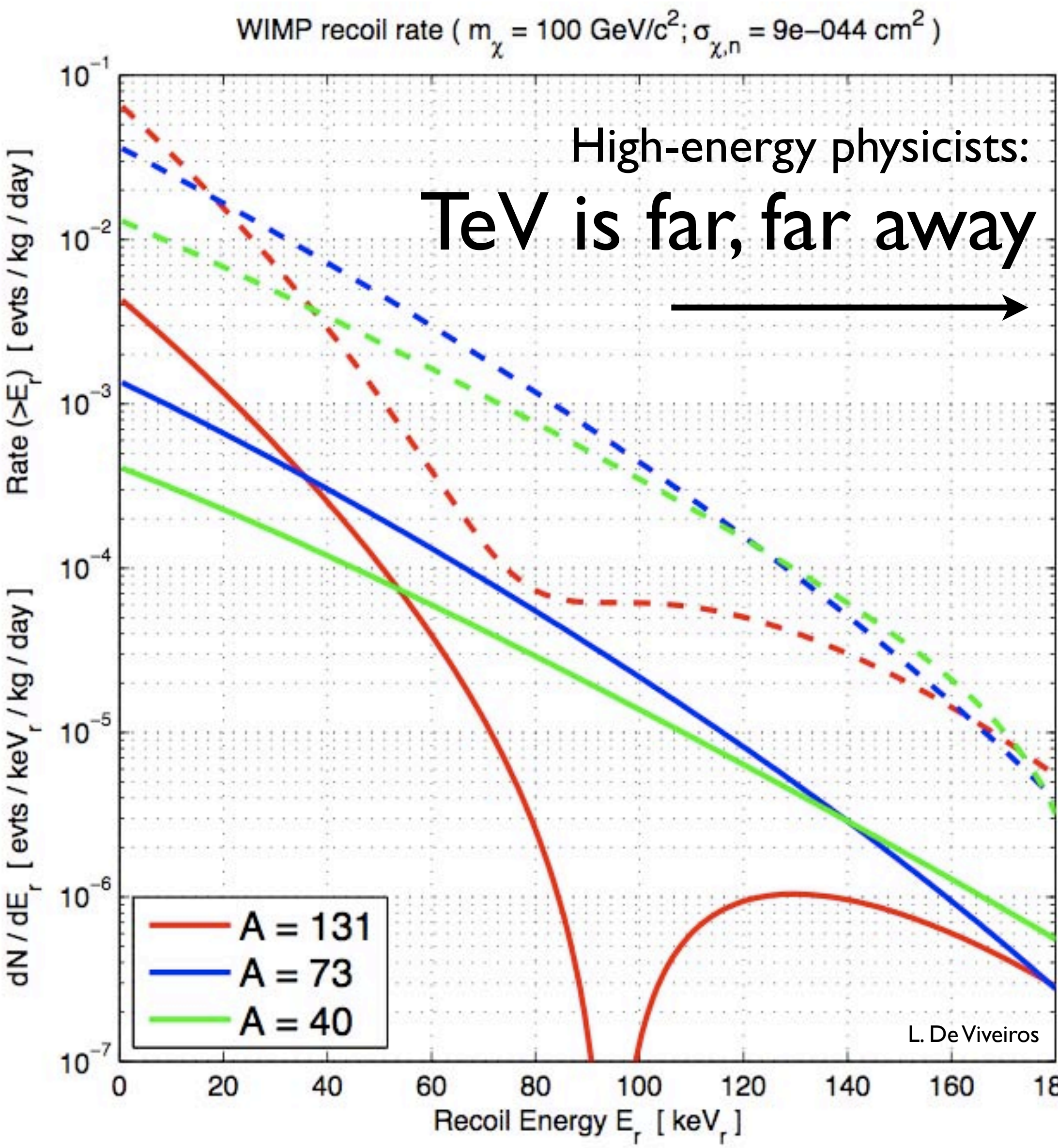




Dark Matter as Weakly Interacting Massive Particles (WIMPs)

- Cross-sections of order of weak scale give good estimate of current relic density
- Independently, SUSY predicts a massive, weakly interacting particle

Dark Matter: Direct Detection



High-energy physicists:

TeV is far, far away

Local Milky Way DM density

$$\rho_\chi \sim 0.3 \frac{GeV}{cm^3}$$

Found it!

Assume Maxwell-Boltzman DM velocity distribution

$$\frac{dN}{dE_R} \propto \left(\frac{e^{-E_R/(E_0 r)}}{E_0 r} \right) \cdot \left(F^2(E_R) \cdot I \right)$$

$I \propto A^2$ (for S.I. interactions)

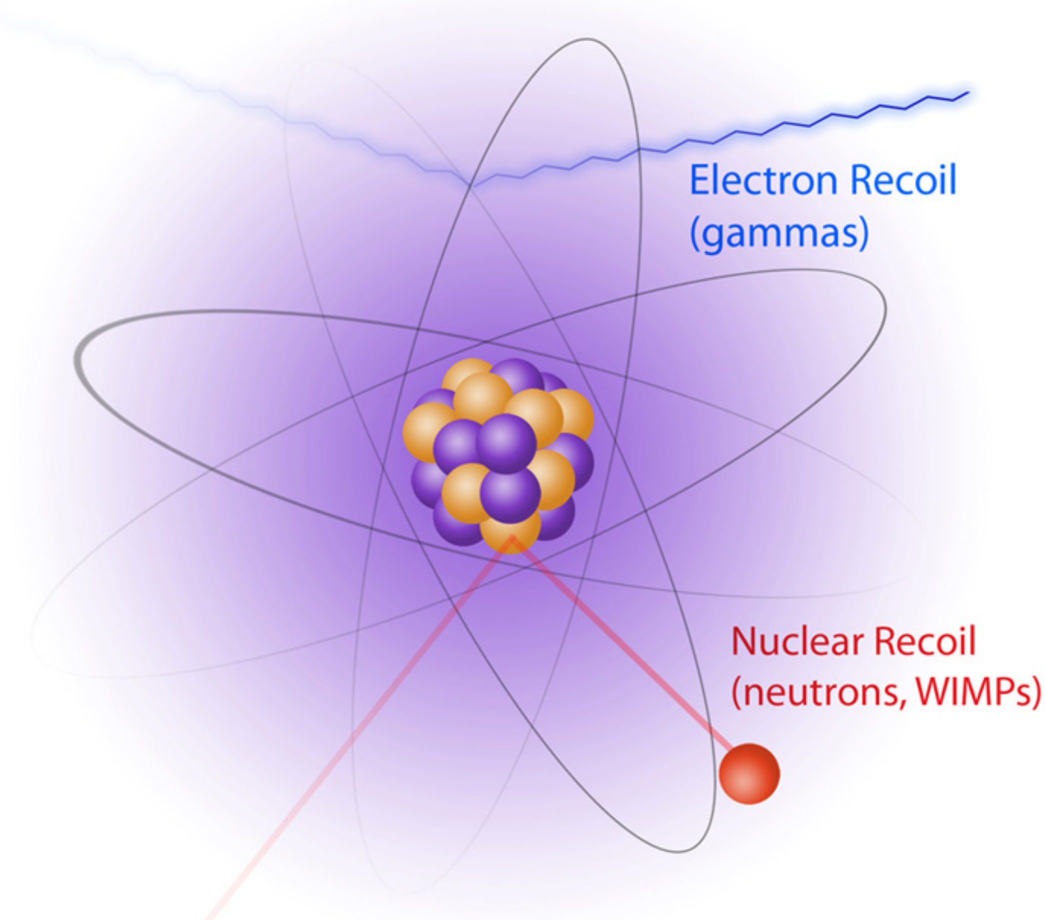
Low-energy threshold is vital

The Plan

The LUX Detection Mechanism

Xenon Signal

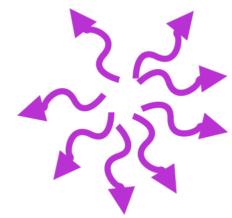
Electron Recoil

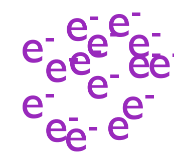


Nuclear Recoil

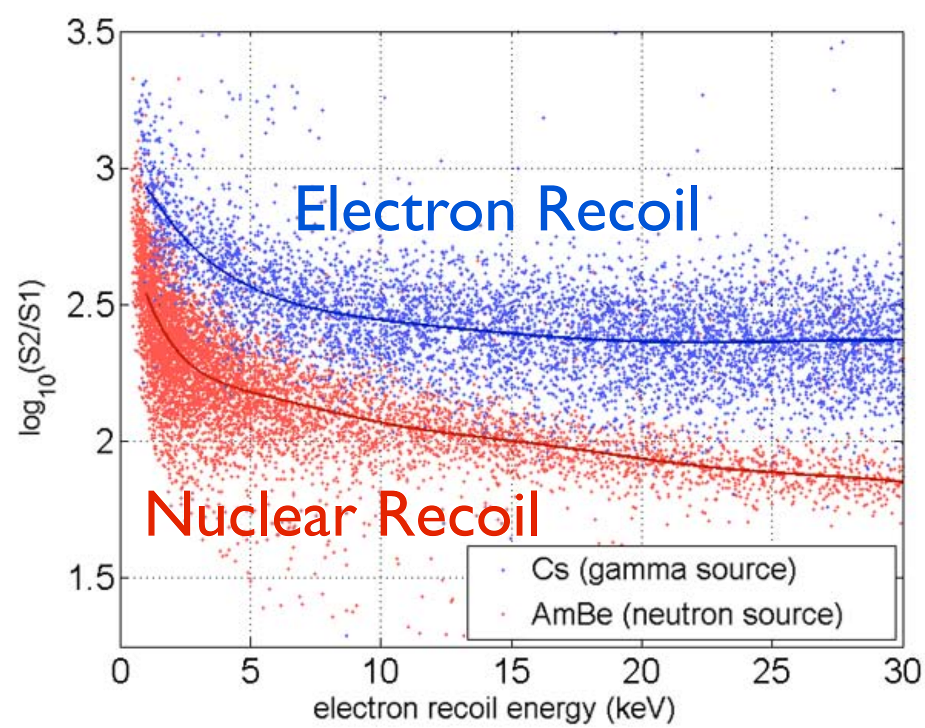
Two signals:

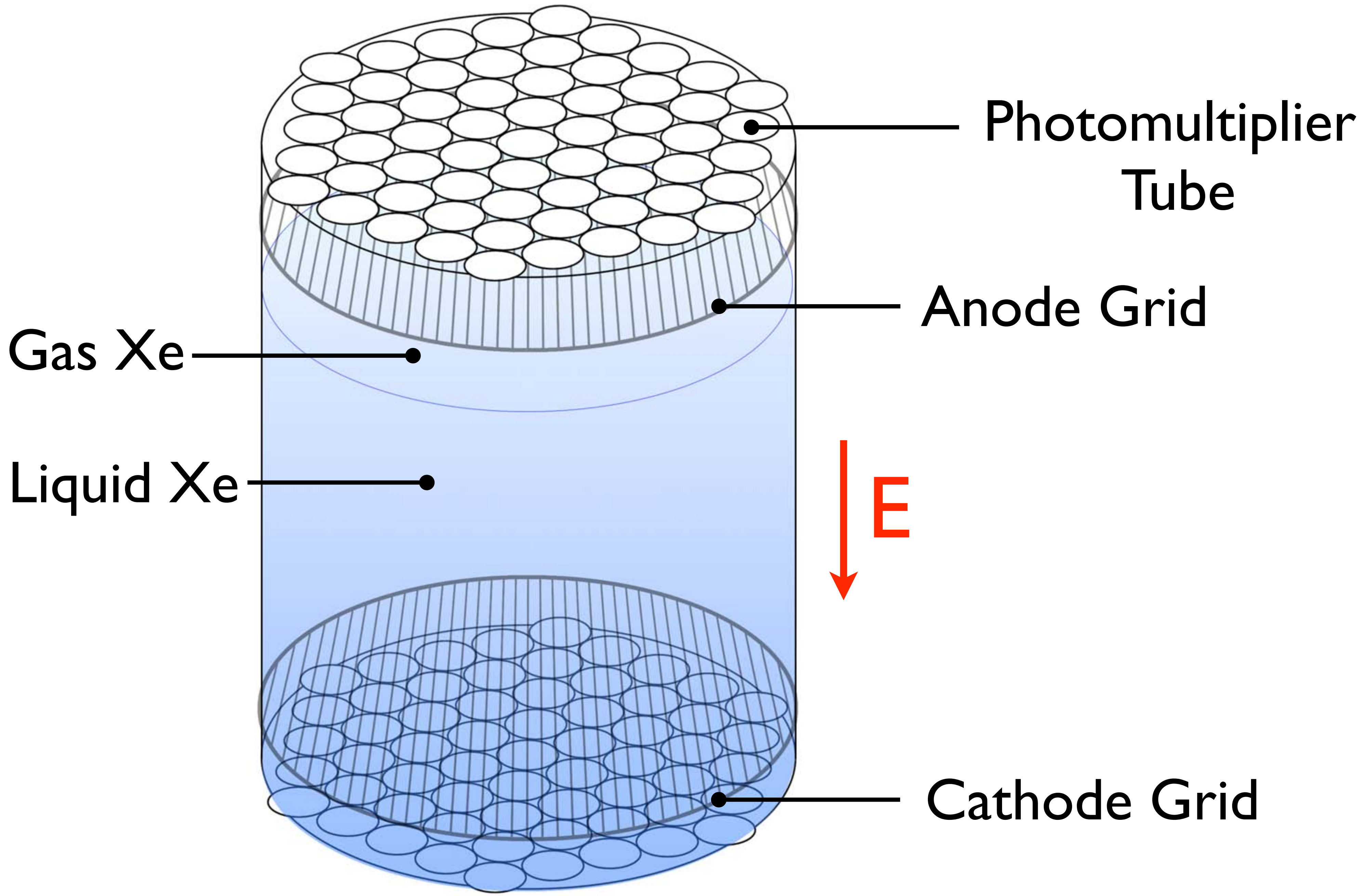
S1 **S2**



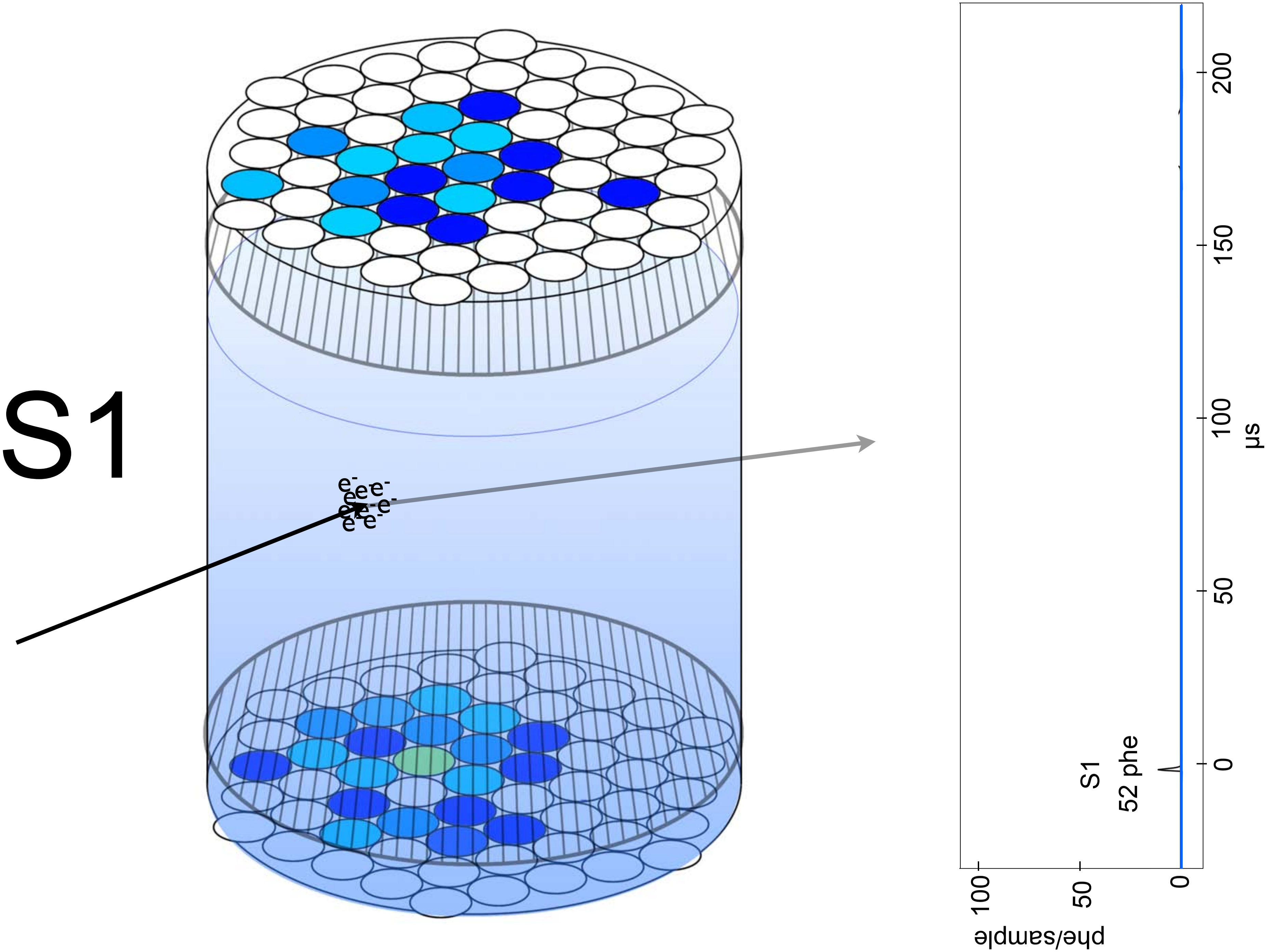


175 nm photons Electrons



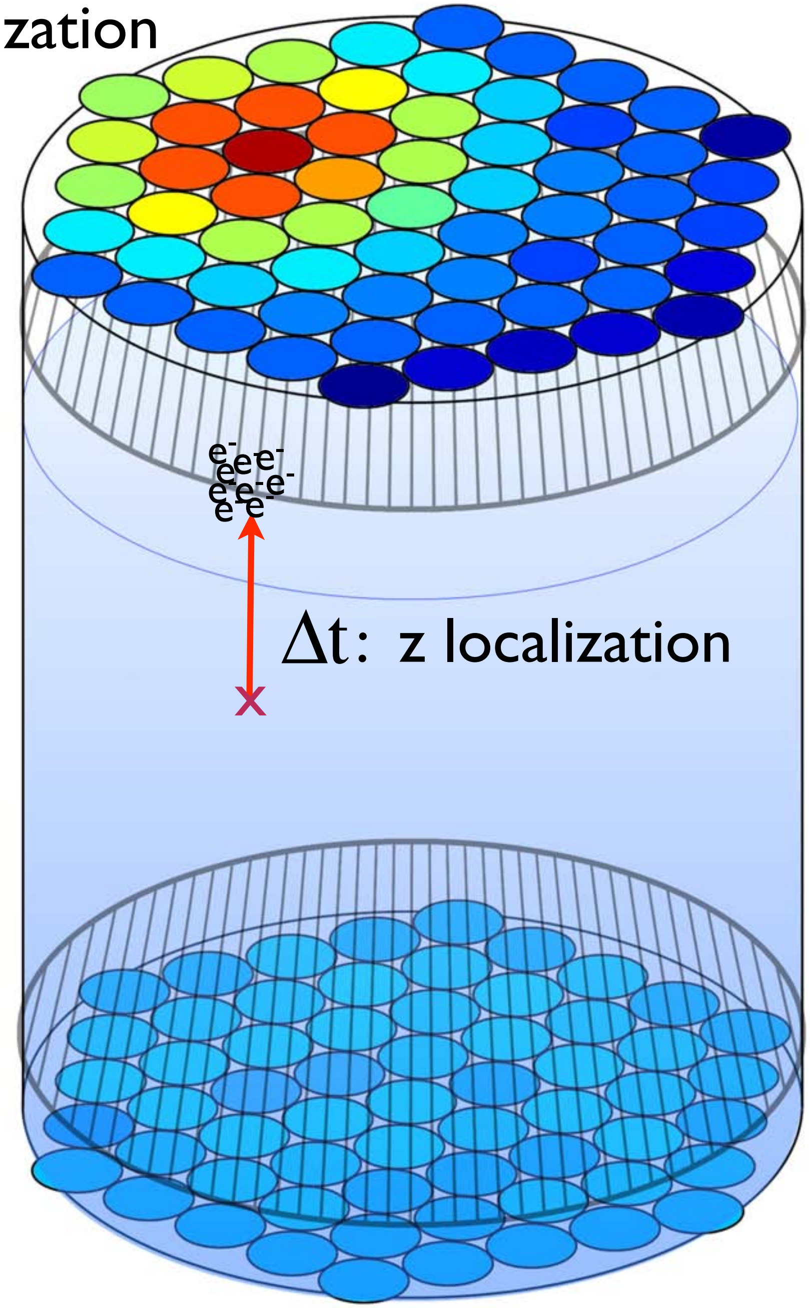

Photomultiplier
Tube
Anode Grid
Gas Xe
Liquid Xe
E
Cathode Grid

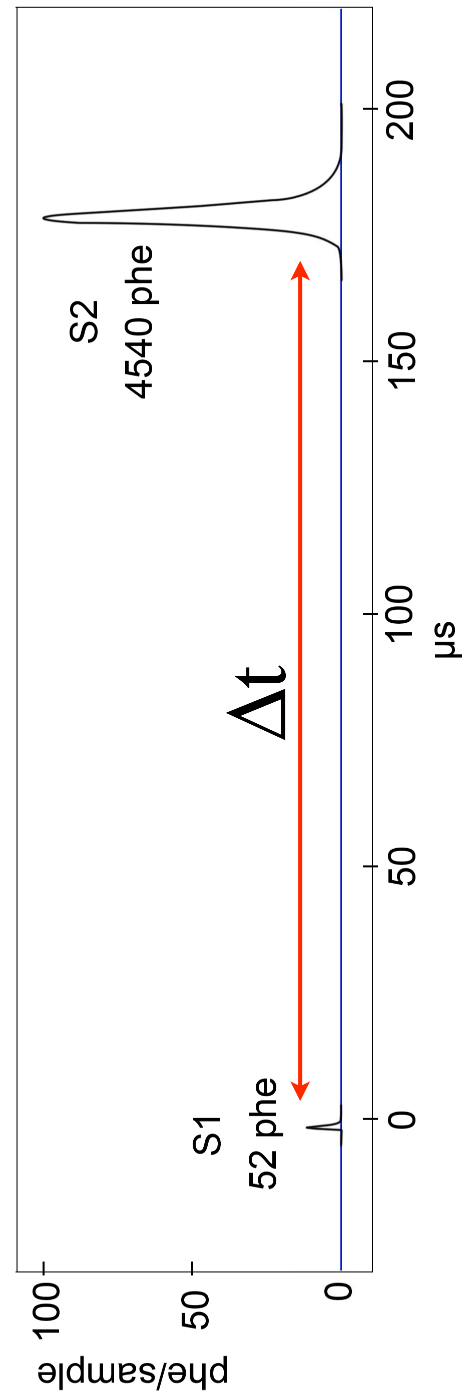
S1



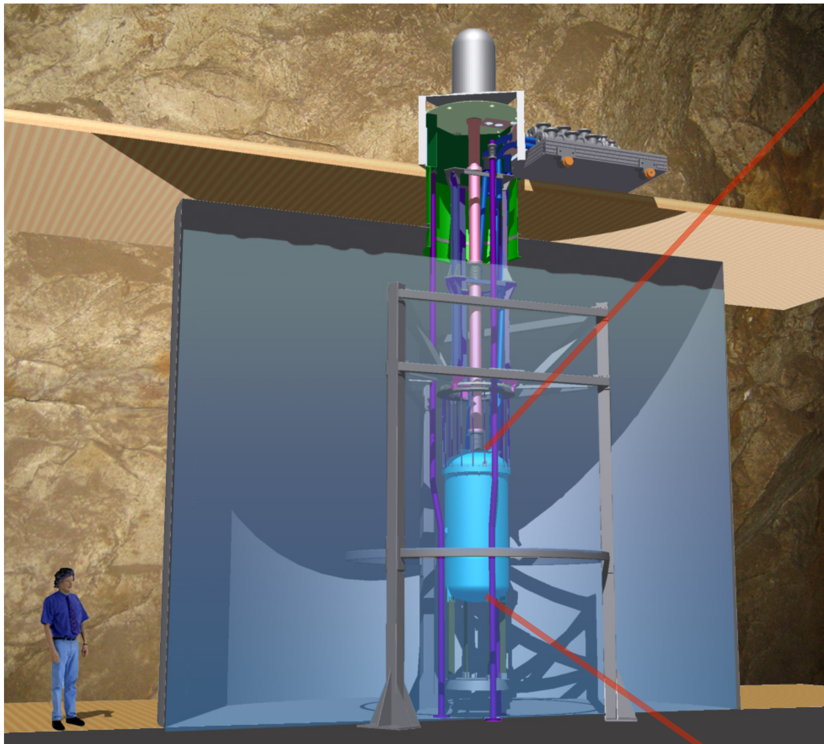
top hit pattern:
x-y localization

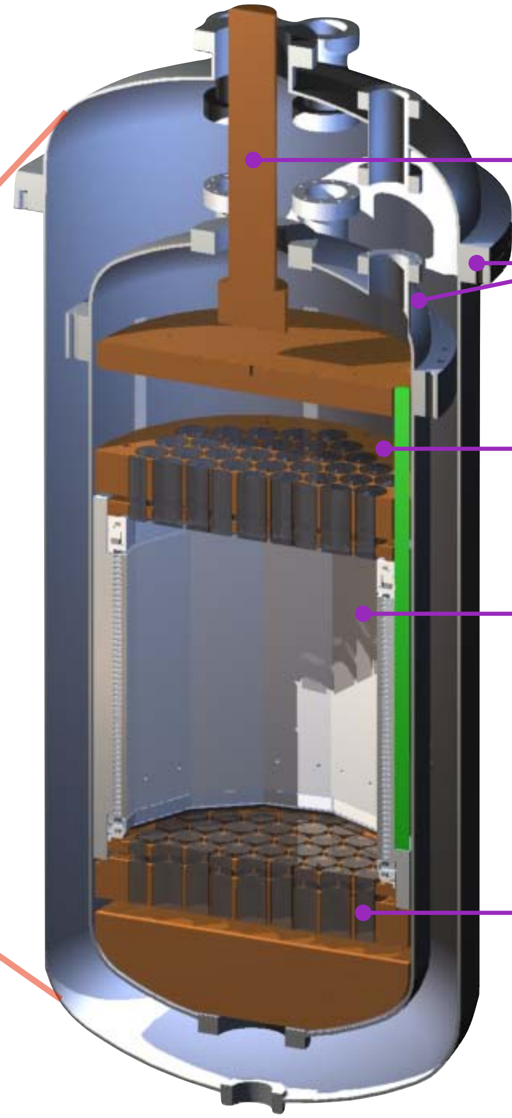
S2



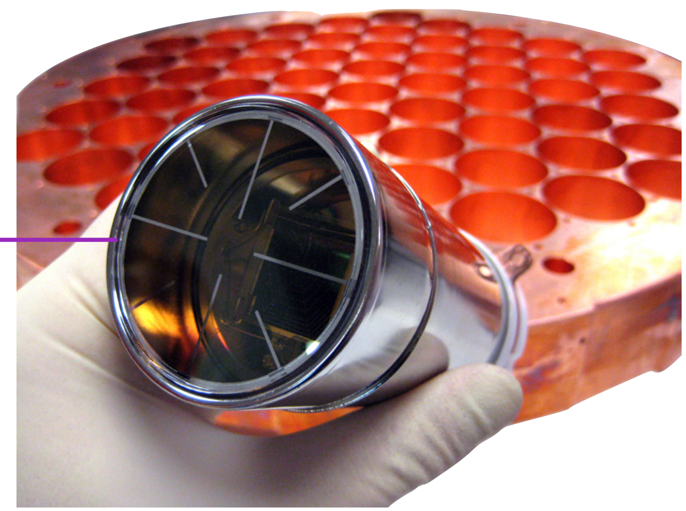


The LUX Experiment





- 350 kg LXe detector
- 122 PMTs (2” round)
- Low-background Ti cryostat
- PTFE reflector cage
- Thermosyphon used for cooling (>1 kW)



2” Hamamatsu R8778
Photomultiplier Tubes (PMTs)

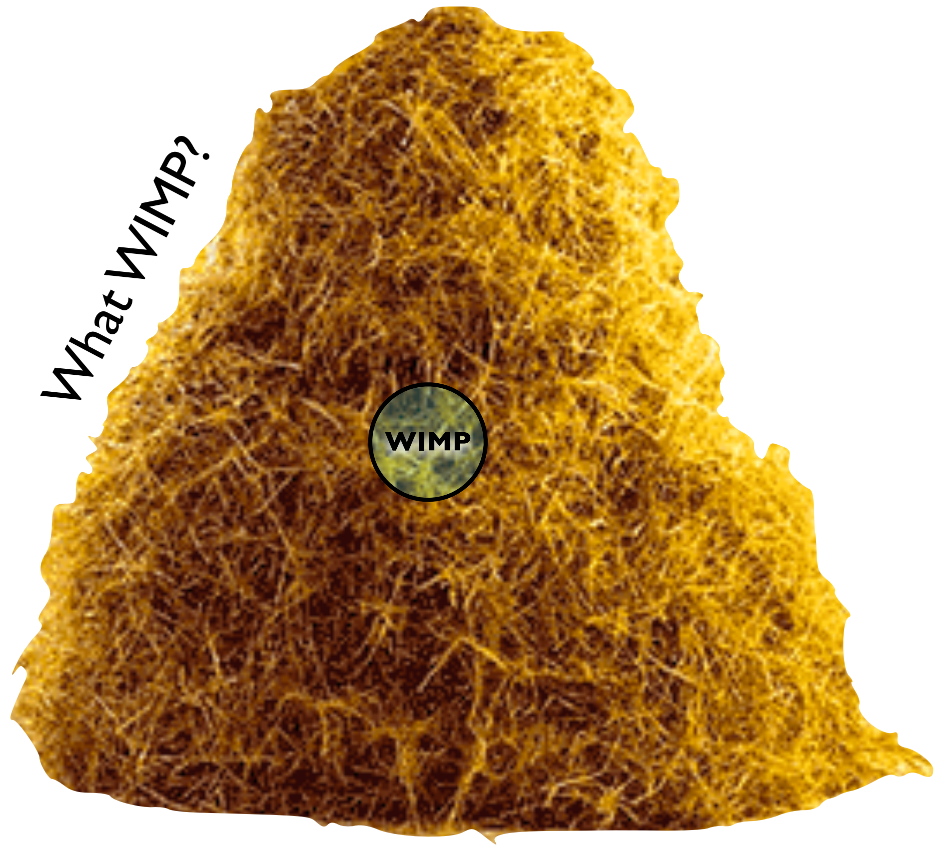
The Challenge

Backgrounds

The Challenge: Backgrounds

(Just to give you an idea)

- Ambient radioactivity:
  - ~100 evts/kg/s
- Human gamma activity:
  - ~10,000 gammas/s
  - Ellis: "What happens if I put a cat in the detector?" - Just don't do it
- Walls (U/Th/K):
  - Concrete: 25/5.5/640 Bq/kg
  - Rhyolite rock: 100/45/900 Bq/kg
- U/Th/K radioactivity is everywhere!
- Muons at sea level:
  - 1/hand/s (50 Hz with >300 MeV deposited in LUX at sea level)



We're looking for a few events/100kg/year!

The Tricks

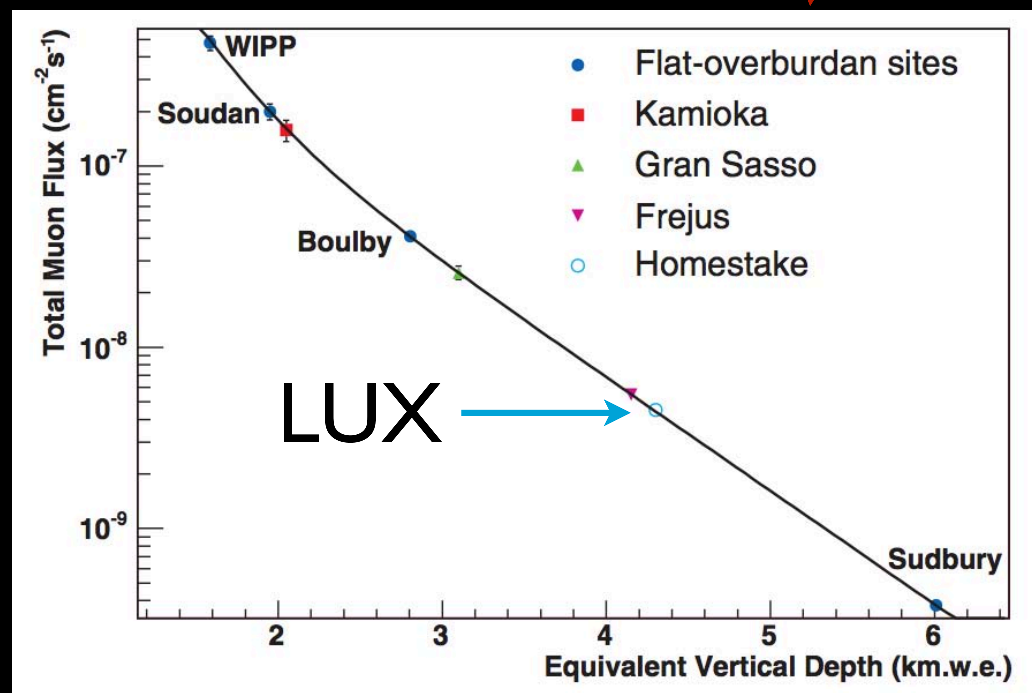
Underground / Self-shielding / Discrimination / Water shield / Material Selection

The Tricks: Underground Operation

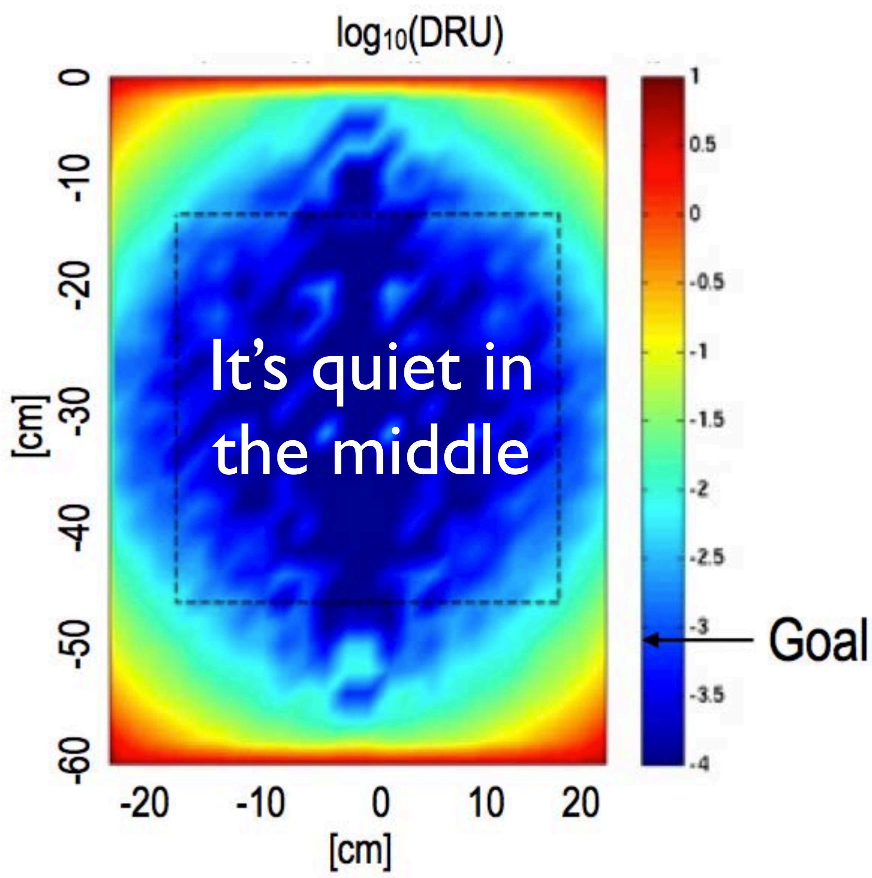
~1 / hand / s

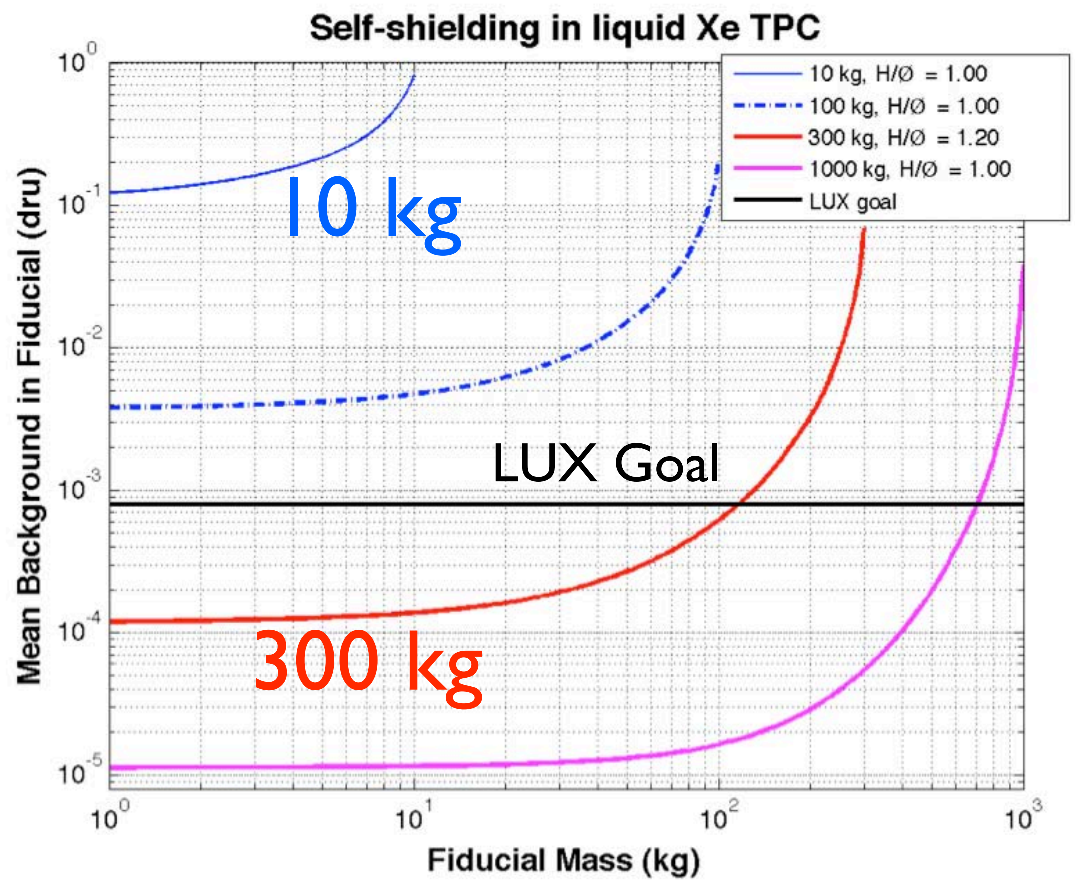
~1 / hand / months

Shhh... it's quiet underground



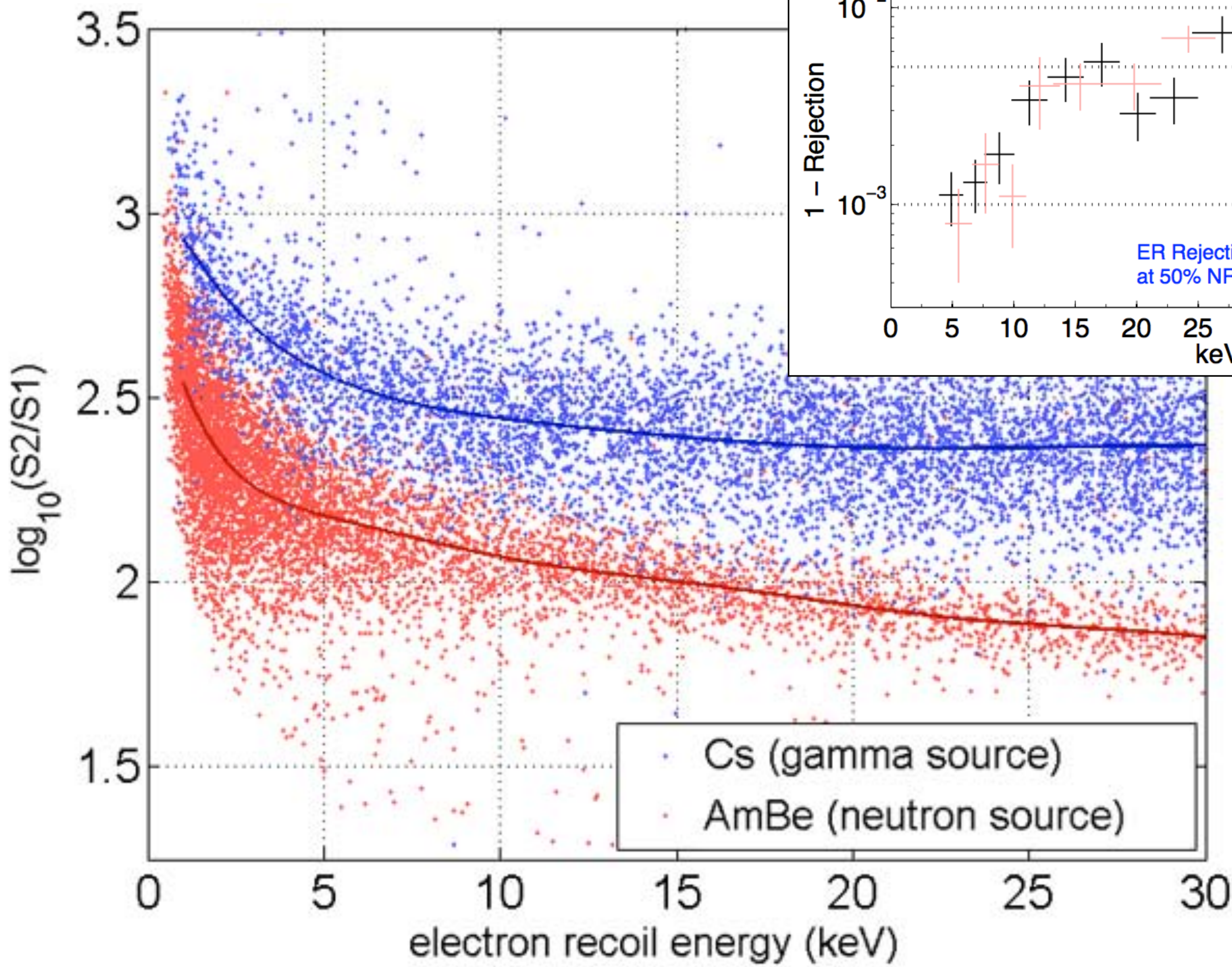
The Tricks: Xenon Self-shielding

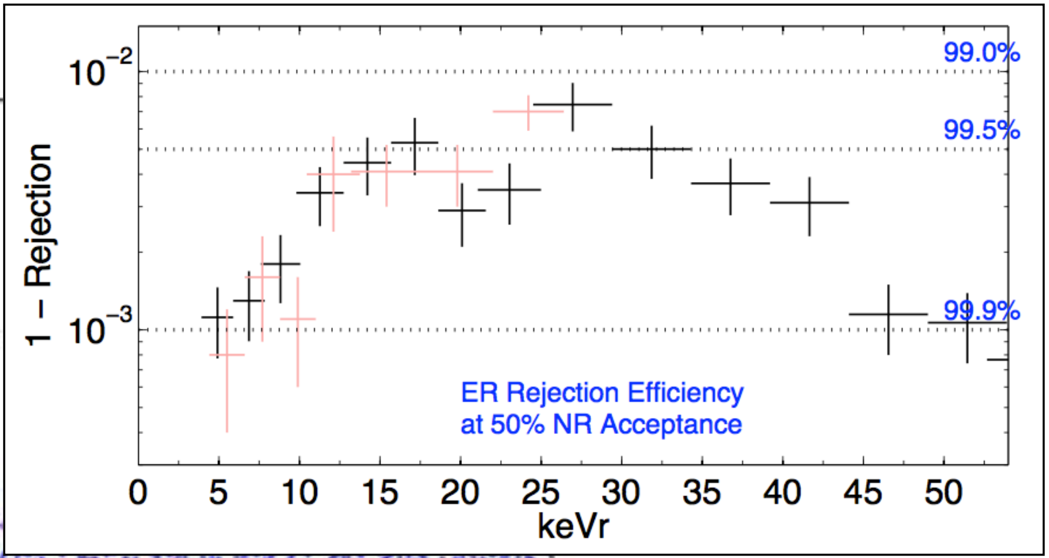




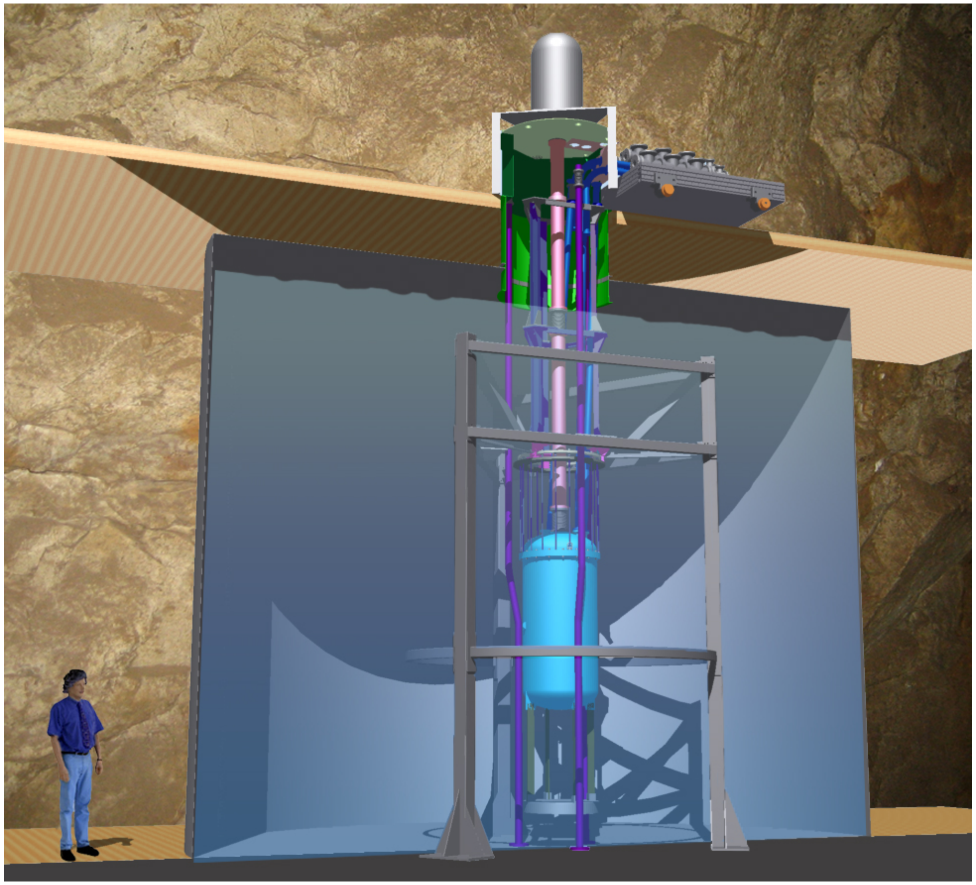
- LXe is a dense target at 3 g/cc
- Self-shielding allows this technology to greatly benefit from scaling up

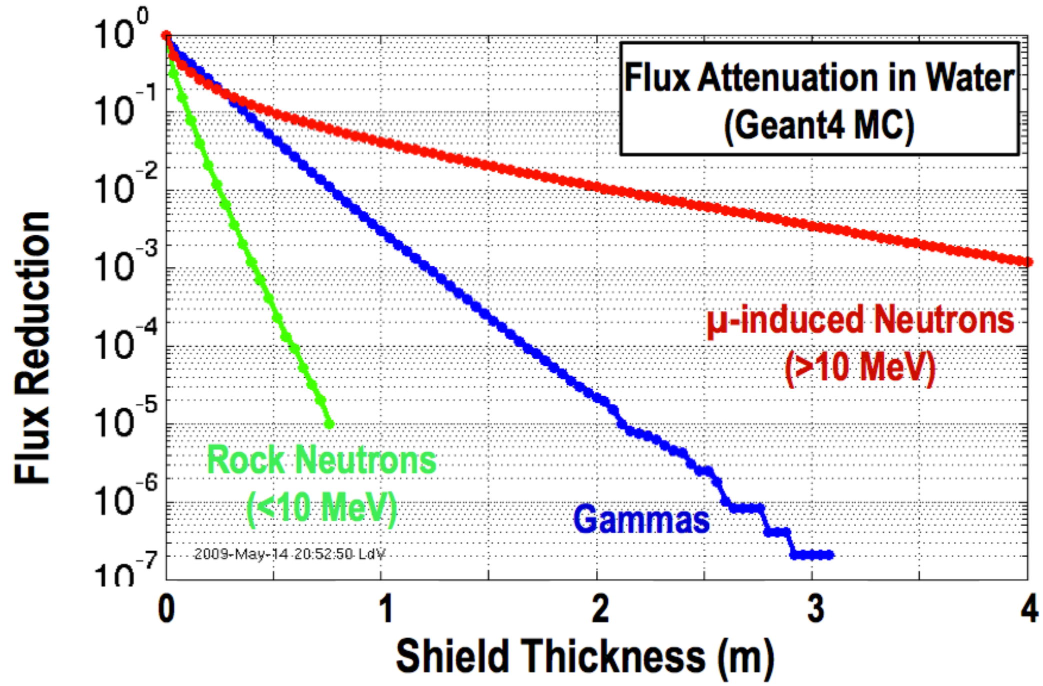
The Tricks: Discrimination





The Tricks: Water Shield





Water shield:

- 8m by 6m tank with 300 tonnes of water
- Reduces gamma background by 10^{-10}
- Reduces high-energy (>10 MeV) neutrons by 10^{-3}
- Water tank is active (Cerenkov), with 20 8-inch veto PMTs, which further reduces external backgrounds

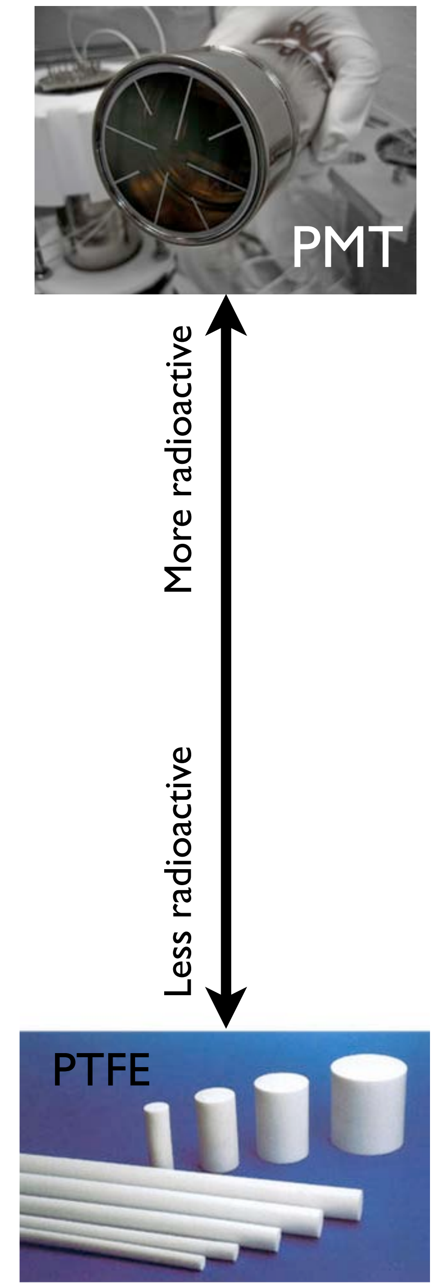
The Tricks: Material Screening and Contaminant Reduction

- PMTs
  - 10/2/65 mBq/PMT (U/Th/K) and 2 n/year/PMT
  - However, multiply by x122 and consider the fact that they are right next to the active region...
  - They are the dominant source of internal background
  - In 30,000 kg-days, in fiducial region and in 5-25 keV_r, all PMTs would contribute:
    - 0.5 gamma events
    - 0.1 neutron events

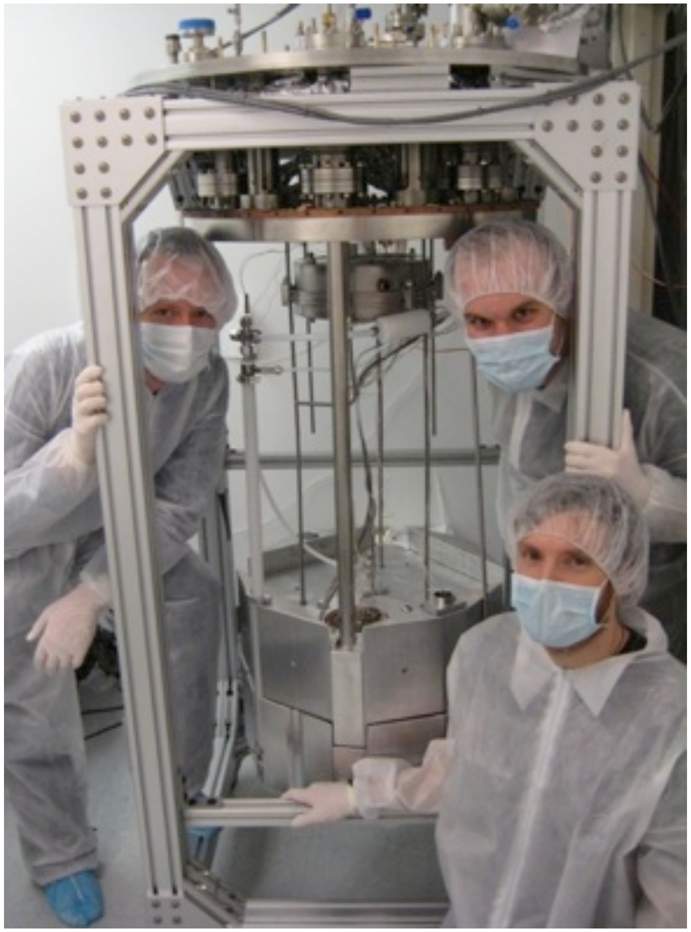
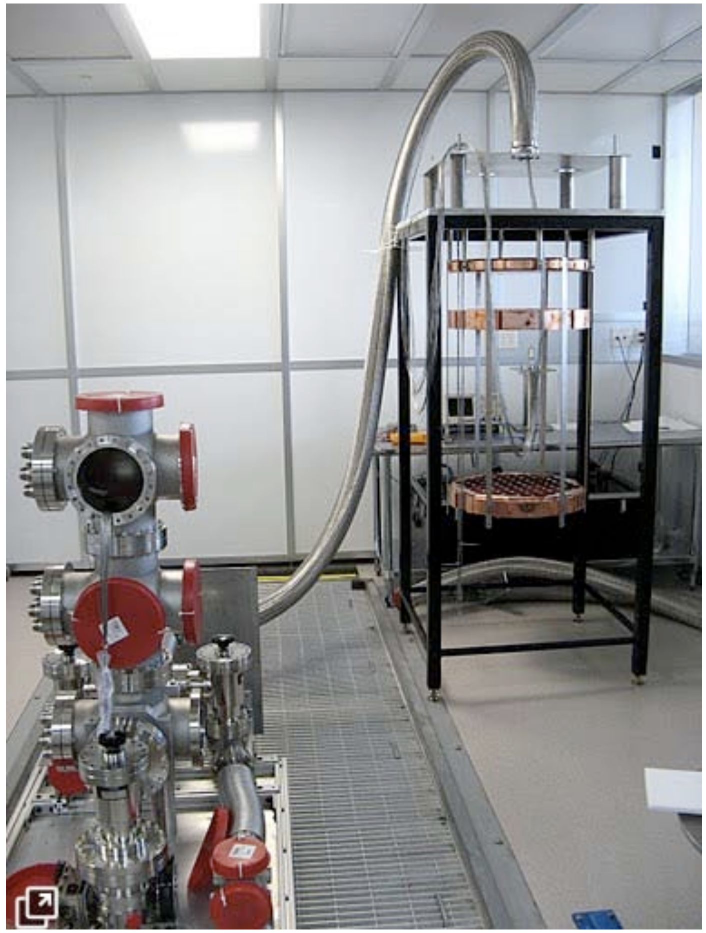
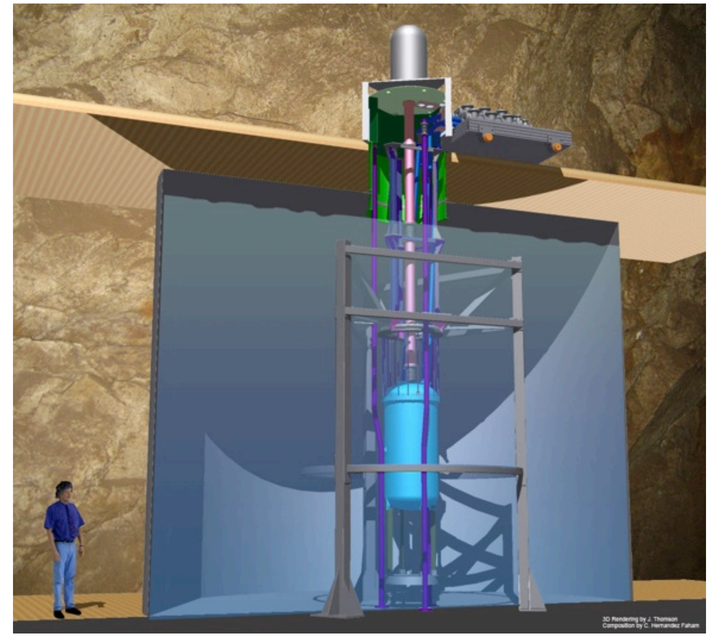
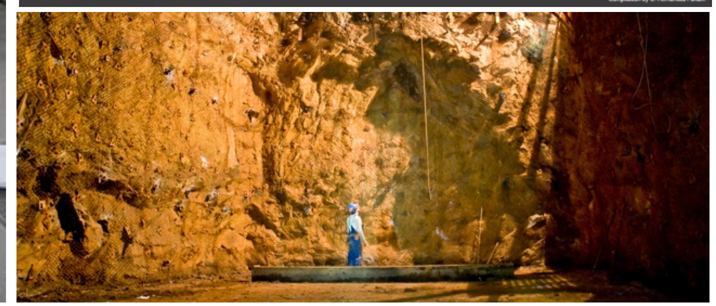
- Titanium Cryostat
  - Very low radioactivity: <0.4 mBq/kg U+Th
  - Largely subdominant

- Rn
  - Cleanroom reduces levels to < 40 Bq/m^3.
  - Minimize exposure, increase airflow

- Kr
  - Present in commercial Xe at ppm level. Reduced to <2 ppt with charcoal column separation



The LUX Program

LUX0.1 - CWRU	LUX - Surface	LUX - Underground
		 
2007-2009	2010	2011+

Past: LUX0.1 at Case Western

- Surface run at Case Western Reserve University during 2007-2009

- Full assembly of LUX subsystems:
  - Cryogenics
  - Recirculation
  - Slow control & safety systems
  - Electronics chain
  - PMT mounts and resistor-chain bases
  - Analysis software

- 50 kg Xe total mass (260 kg Aluminum filler displacer)
- 4 PMT operation, 5 cm active Xe region

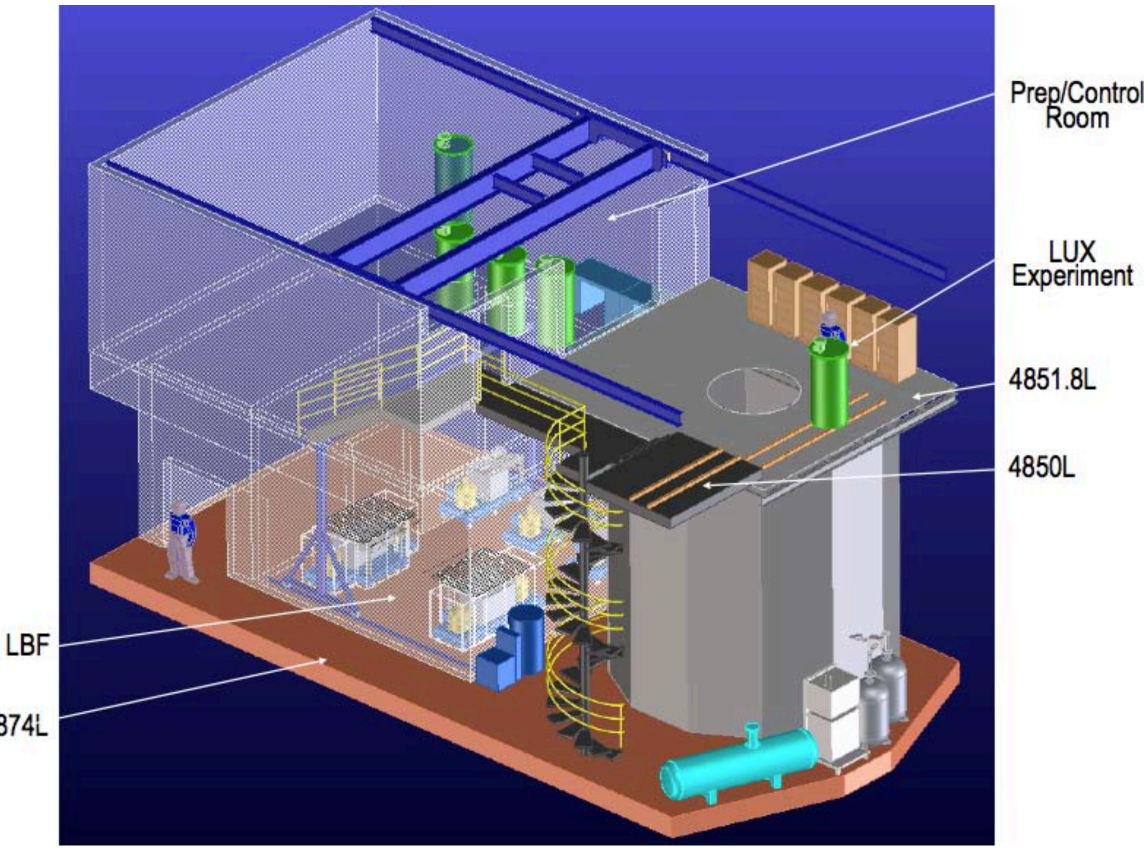
- Very encouraging milestones:
  - Achieved electron drift length > 2 m (purification rate with 9 hr e-folding)
  - Gamma and neutron calibrations

Present: LUX at the Sanford Surface Facility

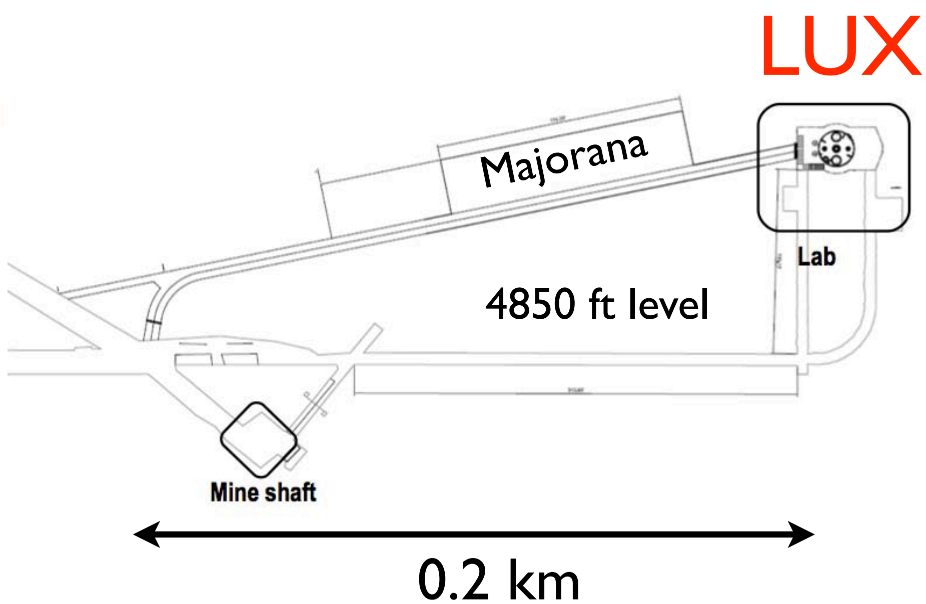
The dress rehearsal

- Full-scale LUX assembly and deployment
- **Duplicate** of the underground layout
  - Smaller water tank (3 m)
  - Cleanroom class 1,000 (will be relocated underground)
- LUX operations since November 2009

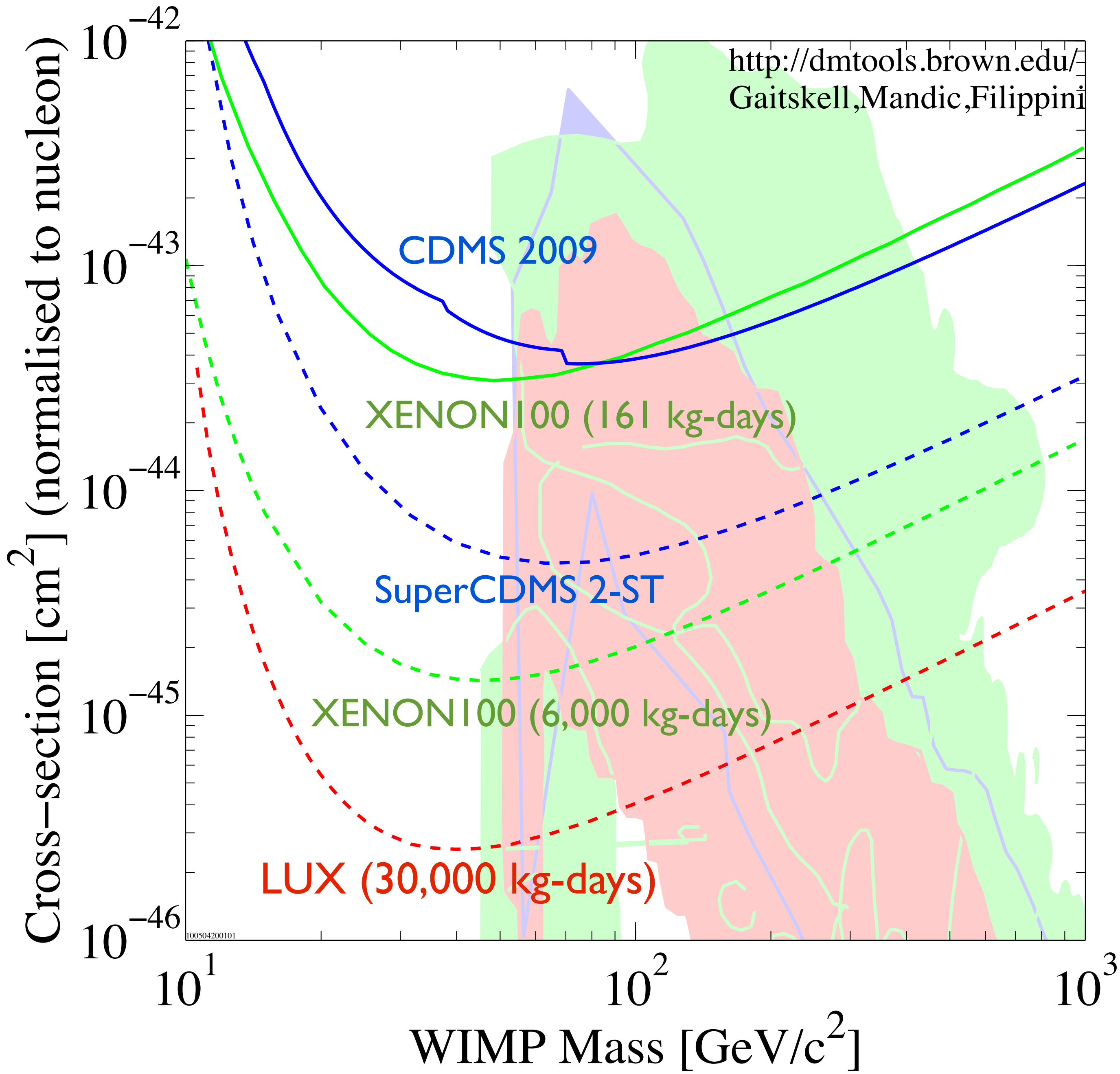
Very near future: LUX Underground (Davis Cavern)

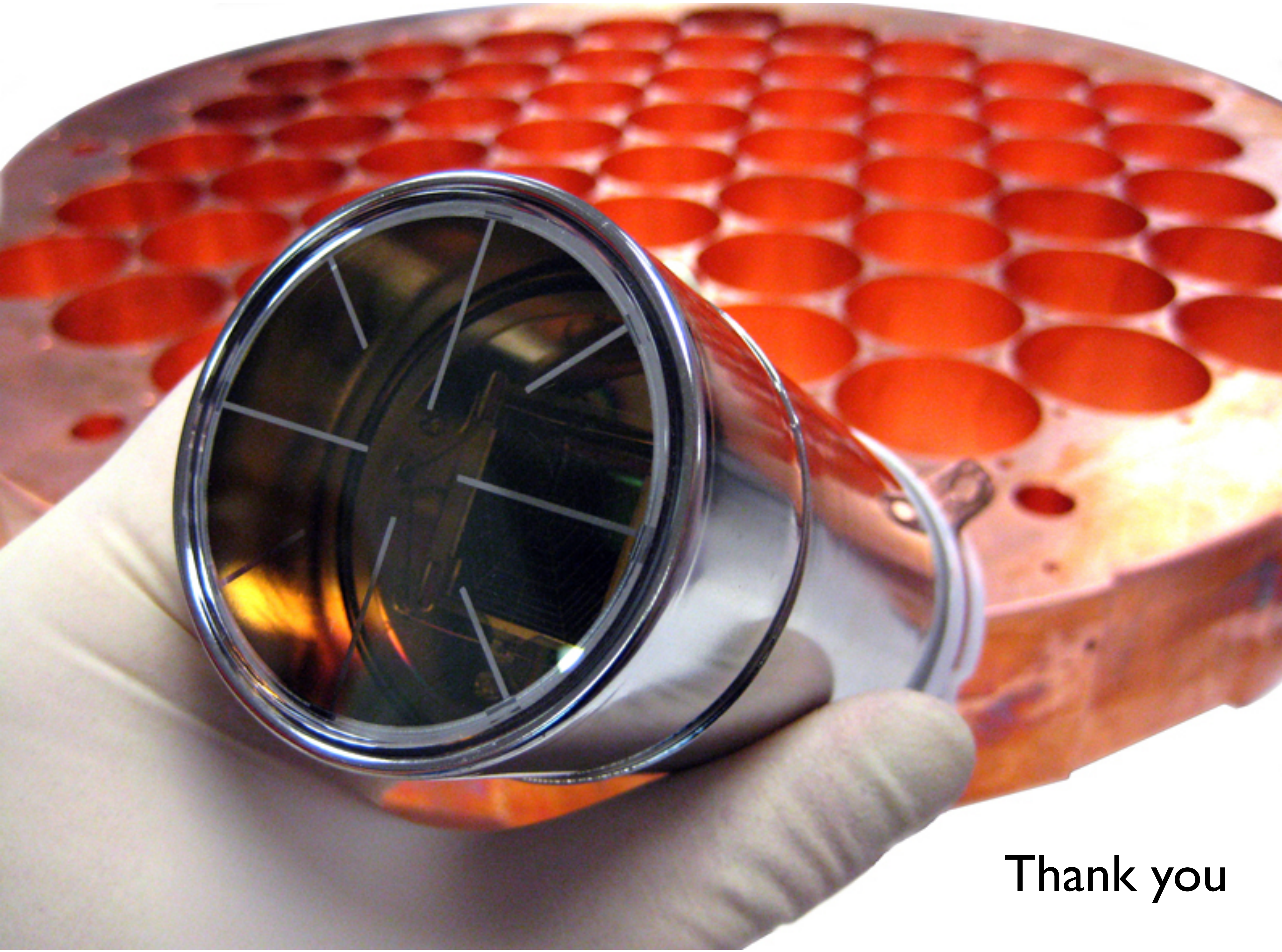


Two story, dedicated LUX 55’ x 30’ x 32’ facility



Projected Sensitivity

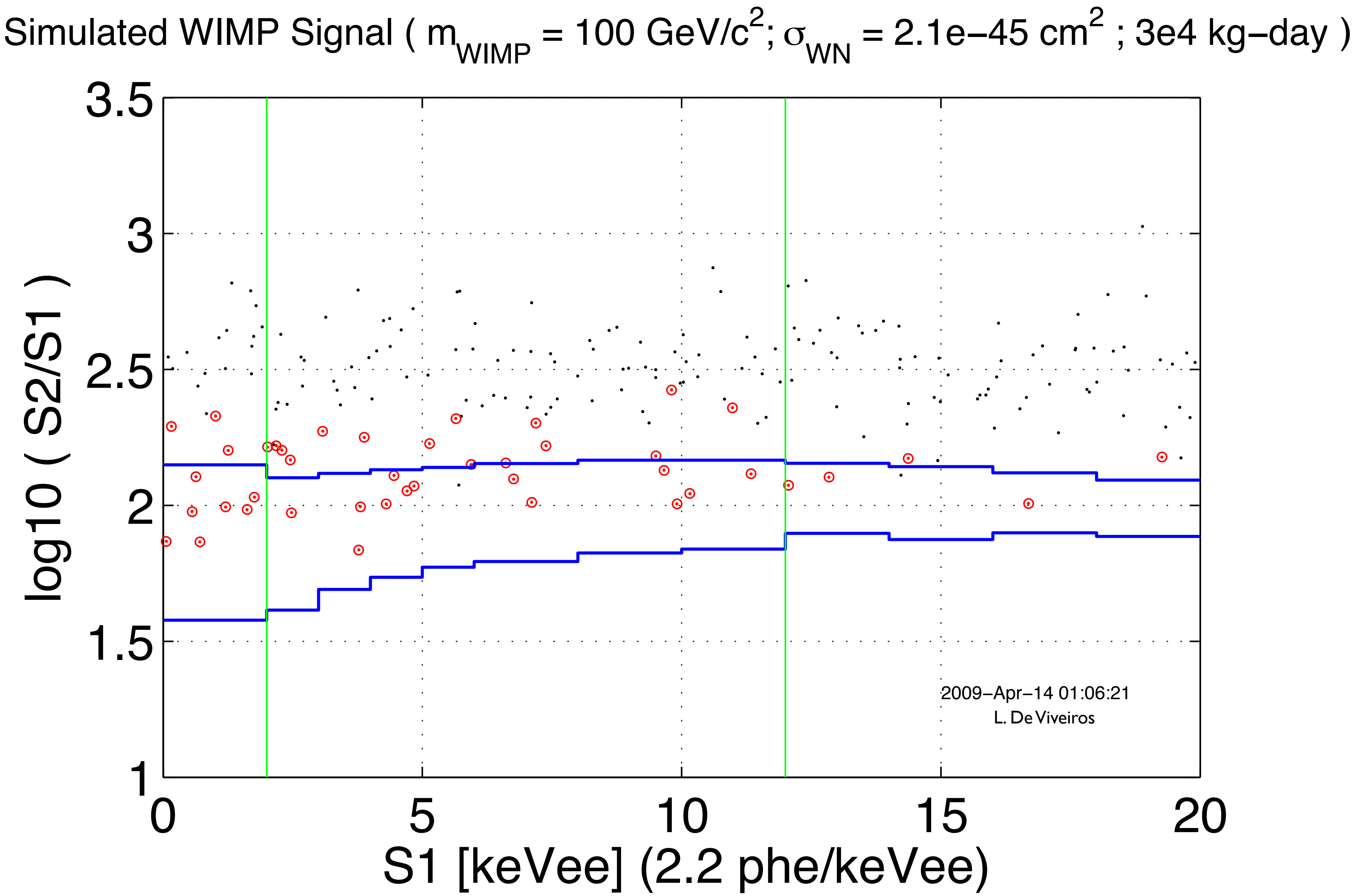




Thank you

Extra Slides

LUX Dark Matter Signal



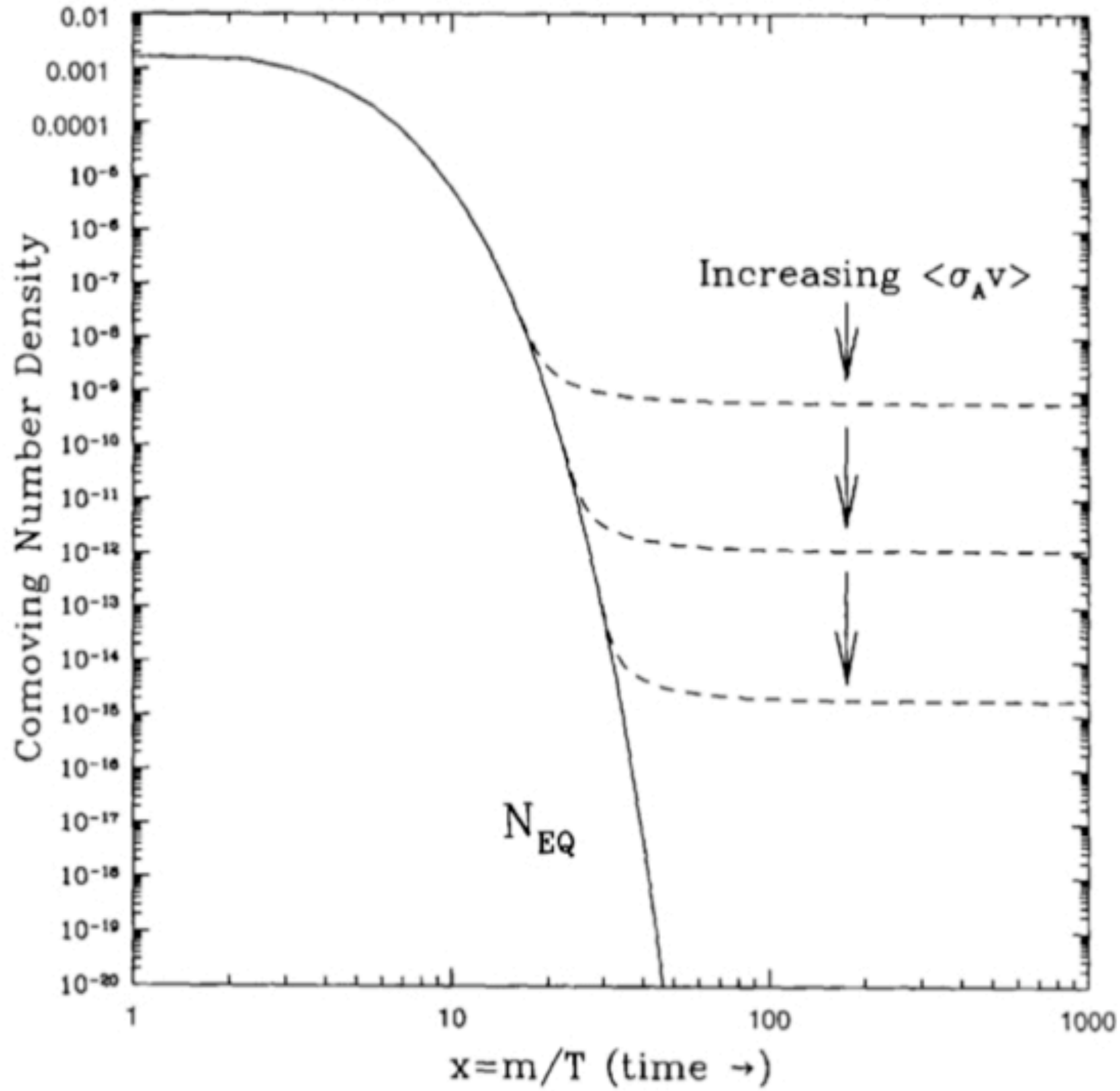
Why WIMPs?

$$\Gamma = n_\chi < \sigma_A v >= H$$

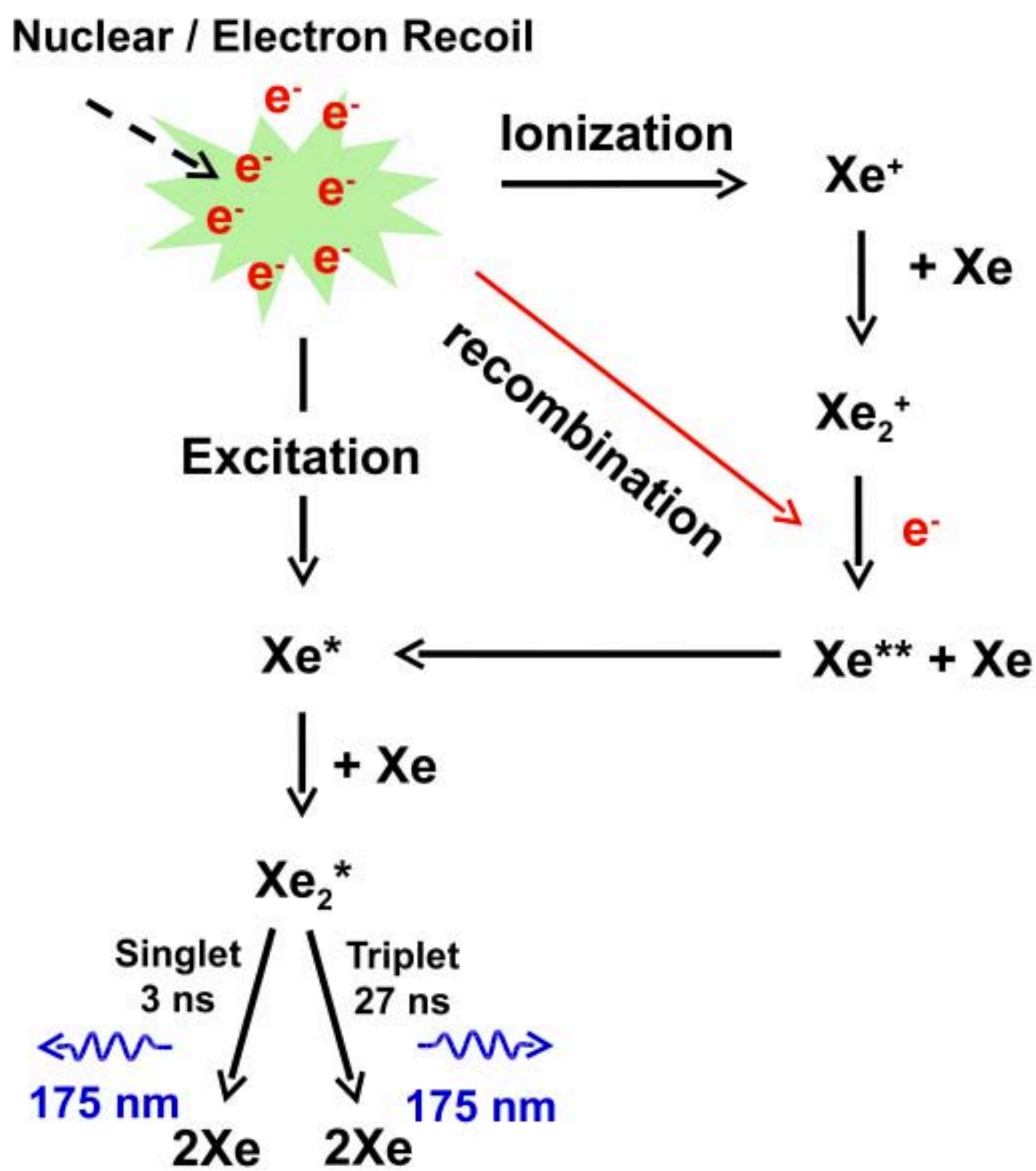
$$\boxed{\Omega_\chi \approx \frac{(0.1pb)c}{h^2 < \sigma_A v >}}$$

$$\Omega_\chi \approx 0.2$$

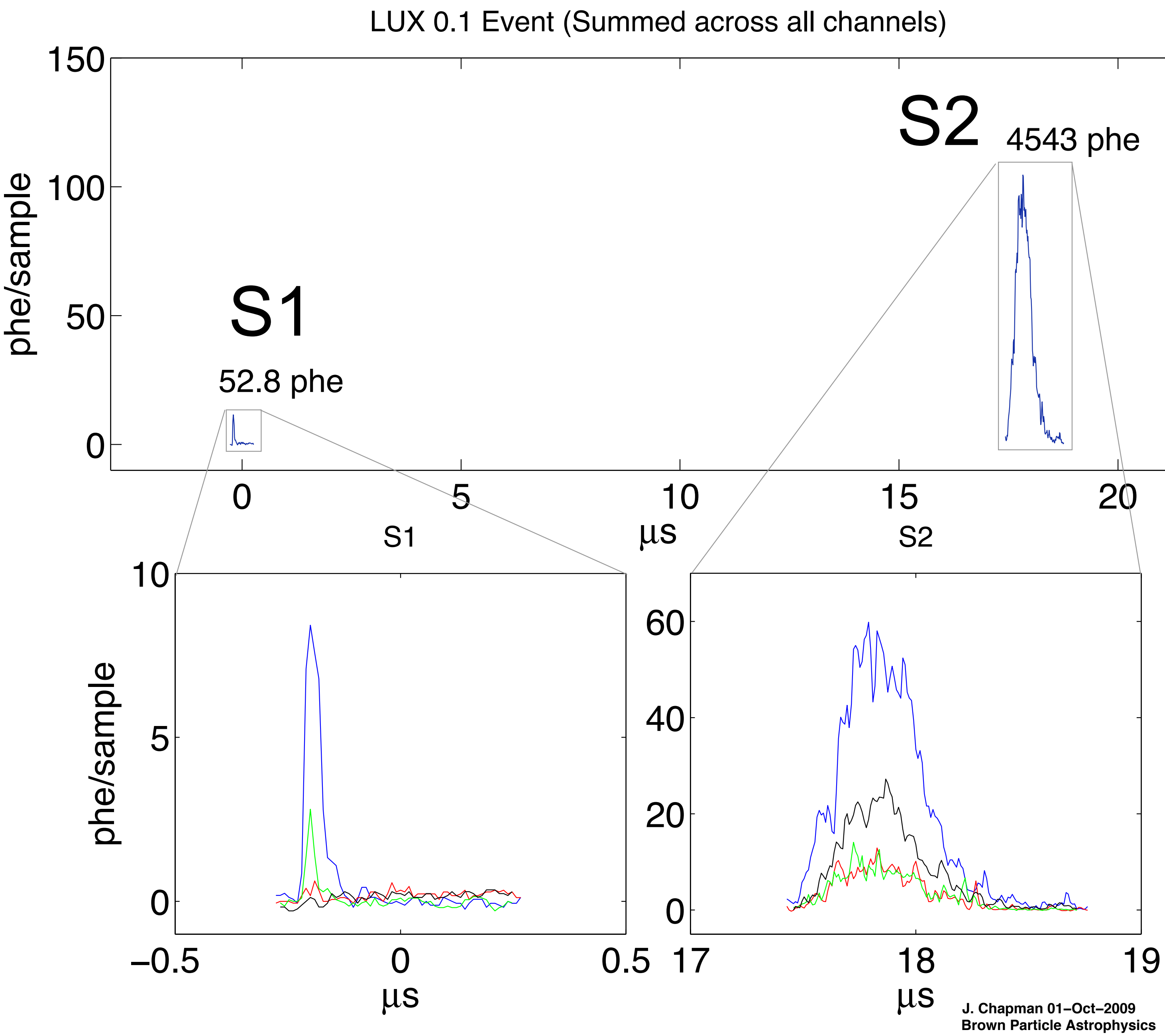
For $< \sigma_A v > \sim 1 pb \cdot c$



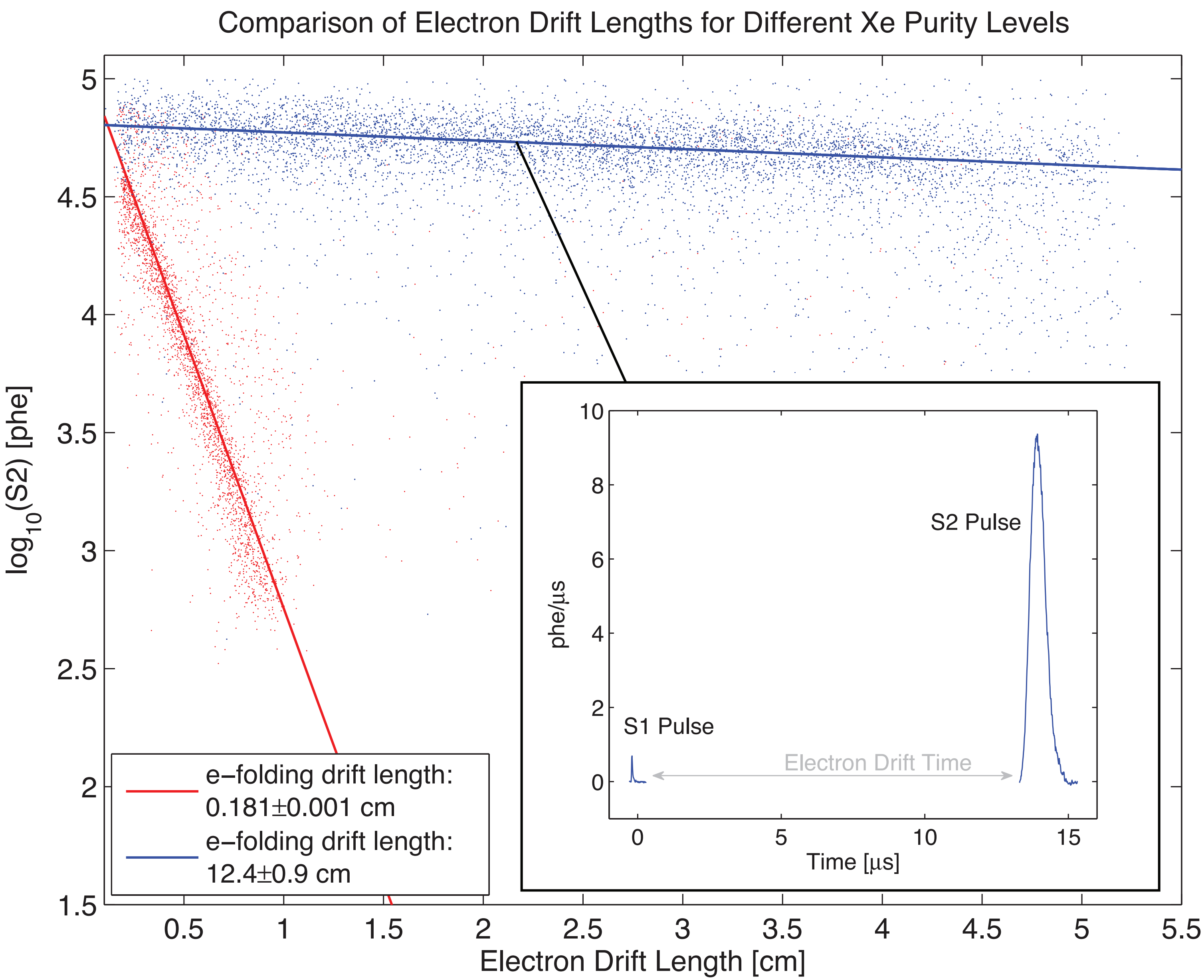
Xenon Signal Generation



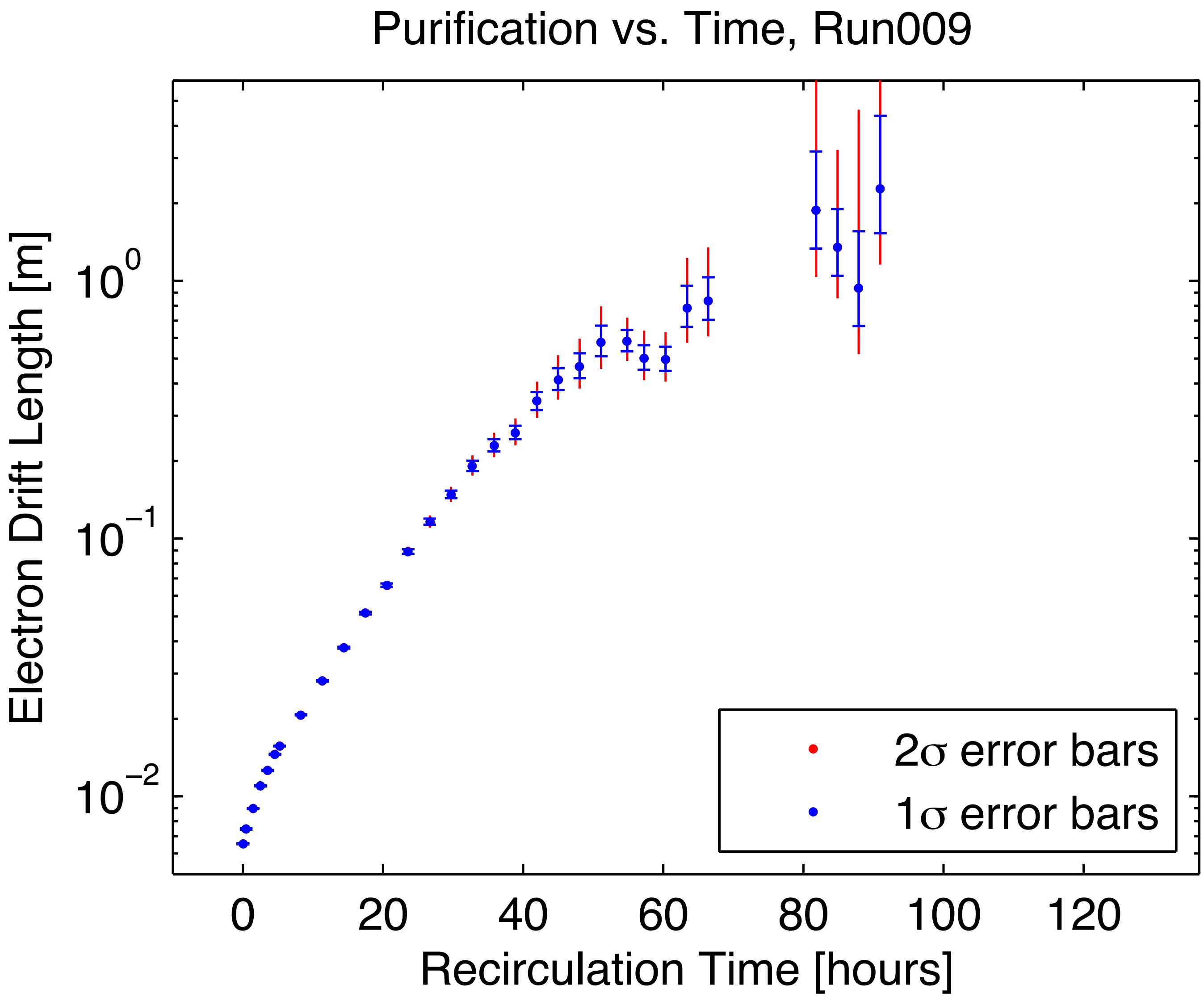
LUX0.1 at Case Western: Pulses



LUX0.1 at Case Western: LXe Purity



LUX0.1 at Case Western: LXe Purity



- ~9 hr purification time constant at 20 slpm (LUX will run at 50 slpm)
- > 2 m electron drift length
- This is an order of magnitude faster recirculation than ever achieved before

LUX0.1 at Case Western: Energy Calibrations